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In this issue:
We present Part I of a technical report authored by Bruce Marler, M.S.E.E., Chief Technical Officer for WooshCom Corporation, and Mukta Kar, Ph.D., CableLabs Senior Member of Technical Staff, on an overview of MPEG-2 digital interfaces.

Baseband MPEG-2 Interfaces

Editor's Note: *This article provides an overview of the main digital interfaces which exist and which are evolving for the transmission of baseband MPEG-2 transport streams. These interfaces are used in cable headends, uplink, studio, and/or transmitter facilities. For the purposes of this article, a baseband MPEG-2 interface is defined as an interface that carries raw digital bits of an MPEG-2 transport stream over an interface with only such encoding as required at the physical layer. While focusing on the physical layer of these interfaces, timing issues that complicate the conversion of one interface type to another will be highlighted.*

MPEG-2 interfaces may be categorized in different ways; some transmit serial bit streams, while others transmit parallel byte streams. An important differentiating factor in categorizing these interfaces is the relationship between the raw clock rate and the rate at which MPEG-2 data is transmitted over the interface. Two types of relationships exist between these rates:

- packet synchronous (PS), and
- packet asynchronous (PA).

In the PS case, the raw clock rate is directly proportional to the rate at which MPEG-2 data is transmitted; such interfaces contain no padding. Whereas in the PA case, the interface's raw clock rate is fixed, while MPEG-2 data is transmitted over the interface at some independently chosen rate up to some maximum allowable capacity. The capacity is determined by the raw clock rate and any overhead required by the interface. The PA interface may be thought of as a fixed-size pipe through which data may be pumped at any rate up to the maximum capacity of the pipe. The PS interface is more like a custom-sized pipe, the capacity of which has been matched to the data rate.

Another differentiating factor is the presence or absence of higher layer protocols that somehow encapsulate the MPEG-2 data packets. According to the definition given above, interfaces with such encapsulation are not truly baseband MPEG-2 interfaces. However, because of the importance of the following two interfaces, the scope of this article has been extended to include them:

- the IEEE 1394 interface, which is emerging as the interface of choice for set-top boxes (STBs), and
- the SMPTE 305M interface, which will extend the ubiquitous SDI interface (259M) to the MPEG-2 environment.

Other interfaces in this category, which will not be explored here, include SONET (OC-3c, OC-12, etc…), which employs rates within the synchronous digital hierarchy (SDH), and both the European (E2, E3, etc…) and North American (DS-1, DS-3, etc…) plesiochronous digital hierarchy (PDH) rates. Over these interfaces, protocol layers, such as asychronous transfer mode (ATM) and ATM adaptation layers (AAL) for MPEG-2 transport, may be added.

The table on page 2 provides a brief summary of the more popular interfaces and their primary characteristics, with a more detailed description in the paragraphs which follow.

Not listed in the table are older proprietary interfaces developed before a standard was available. These interfaces include GI's HSI, parallel RS-422, serial RS-422, parallel ECL, serial ECL, and TTL variants. For the most part, these proprietary interfaces are passé as they have been surpassed by standard interfaces, such as DVB-ASI or SMPTE 310M. If an older interface is encountered, the pertinent equipment manufacturer should be contacted for further details.

IEEE 1394

The IEEE 1394 interface will be used heavily in digital consumer appliances and desktop computers. It also may find implementation in the studio environment. It is a low-cost, high-performance interface with robust, consumer-friendly features. The IEEE 1394 is an attractive consumer interface because:

- the high-performance, low-cost bus supports simultaneously asynchronous (guaranteed delivery) and isochronous (guaranteed timing) transport on the same bus,
- plug-and-play features make it user-friendly—device live attach/detach prompts the network to self-configure and resume normal functioning,
- multiple devices are supported in a

Interface Name	Type	Serial/Parallel	Max Distance (feet)	Raw Clock Rate (MHz)	MPEG-2 Data Capacity (Mbps)	PHY Layer Encoding	Electrical Levels	Connector/ Cable Type
DVB-ASI	PA	S	300	270	214	8B/10B	Fiber Channel FC-0	Coax 75Ω & multi-mode fiber
Divicom M2S	PA	S	75	270	100	8B/10B	Custom Levels	In SMA–50Ω Out SMB–50Ω
DVB-SSI	PS	S	450 for coax	<105	Same as clock rate[1]	Biphase Mark	Custom see EN 50083-9	Coax 75Ω & Fiber-optic
SMPTE 310M	PS	S	300	19.39 & 38.78	Same as clock rate	Biphase Mark	AC-coupled ECL	Coax–75Ω
SMPTE 305M (SDTI)	PA	S	984	270 360	200–225 270–300	Scrambled SMPTE 259M	Fiber Channel FC-0	Coax–75Ω Fiber-optic
DHEI	PS	S	16 12	29 & 39	Same as clock rate[1]	None	Diff ECL	Simplex 15 Pin HD-22 Duplex 26 Pin HD-22
SWIF	PA	S	33	54	52.3	Scrambled & Layered	660 nM	Fiber-optic–HP Versatile Link
DVB-SPI	PS	P	unknown	<13.5	108	None	LVDS	25 Pin D type
Divicom M2P	PS	P	30	0.5–12.5	8*Clock Rate[2]	None	RS-422	25 Pin subD
IEEE 1394	PA	S	13.5	98.304 196.608 393.216	Unknown	Only Data-strobe	Custom Diff Low Voltage	4- or 6-pin IEEE1394 110Ω Twisted Pair

[1] Same as clock rate unless forward error correction (FEC) or FEC gap is present where FEC bytes were present. In the latter case, the maximum capacity would be 188/204 times the raw clock rate of the interface.

[2] The data rate can be lower than 8*Clock Rate if there is an inter-packet gap for optional error correction codes. This inter-packet gap is programmable and can be from 0 to 255 bytes long.

networked environment and peer-to-peer communication is allowed, and

- it is available at various bitrates—100 Mbps, 200 Mbps, and 400 Mbps. The IEEE 1394b committee is working on standardizing 800 Mbps and 1.6 Gbps rates.

The SCTE document, *DVS194 Rev. 1*, defines the use of this interface at the consumer site when establishing an interface between an OpenCable STB and a digital television.

The IEEE 1394 interface allows peer-to-peer communication of asynchronous and isochronous data. Asynchronous communication is utilized for guaranteed data delivery, whereas isochronous transmission is used for time-sensitive communication, such as that required by MPEG-2 packets.

The fixed-clock frequency implies that IEEE 1394 is a PA-type MPEG-2 interface. Because the IEEE 1394 bus is shared, an arbitration scheme exists to allocate bus usage. This arbitration scheme cannot guarantee that each MPEG-2 data packet is on the bus at any given moment in time. Therefore, a mechanism needs to be implemented to compensate for introduced jitter.

The arbitration method involves time stamping each MPEG-2 packet with its intended delivery time. The time indicator used for this time stamping is the cycle time register (CTR) maintained by each node on the bus (which is synchronized by a scheme orchestrated by the cycle master on the bus). The CTR is updated internally in each node at a rate of 24.576 MHz. This time stamp is contained in a 4-byte field called the source packet header, which is appended before the MPEG packet, thus creating a 192-byte source packet. The receiving node then is responsible for buffering the received IEEE 1394 packets. Using the time stamp, data is read from that buffer at the appropriate time so that the original MPEG-2 data stream's timing is reconstructed. This process removes any bus-induced jitter from the MPEG-2 transport stream.

DVB-ASI

The DVB-ASI interface has become popular for use with infrastructure equipment. The coax version has become the interface of choice for infrastructure equipment in such facilities as cable headends or uplink sites. The ETSI EN 500083-9 standard specifies a 75Ω coax cable interface and a multi-mode fiber-optic interface that uses LED emitters. Maximum cable length is limited by a minimum receiver sensitivity of 200 mV for a 135-MHz transmitted signal of 720mV (or 11 dB of attenuation); for RG-59 cable, this corresponds to roughly 300 feet. Length can be increased by using cable with better attenuation characteristics.

DVB-ASI is a fixed-frequency serial interface with a clock rate of 270 Mbps that transmits MPEG-2 data in PA fashion. The physical layer is based upon a subset of fiber channel levels (FC-0 and FC-1), and makes use of the 8B/10B channel coding of that standard. Using this coding technique, 8-bit data bytes are translated into 10-bit codes according to the 8B/10B translation table and the running disparity of the bit stream. The running disparity is calculated as the number of ones minus the number of zeros sent. This is proportional to the DC level of the bit stream. The 8B/10B table includes two entries (a positive and negative disparity representation) for each 8-bit code. The entry used is selected to keep the running disparity between +1 and –1 so that the DC balance is maintained near zero.

The 10-bit words then are serialized and are transmitted across the serial interface at a speed of 270 Mbps. To ease synchronization, the MPEG-2 sync byte (0x47) must be preceded by two consecutive special 10-bit codes (comma characters). The comma character also is referred to as a K28.5 code word (from the 8B/10B tables), the synchronization word, or a stuffing byte. The combination of 8B/10B encoding and two comma characters results in a maximum data capacity of 213.7 Mbps.

DVB-ASI interfaces must support 188-byte MPEG packets and optionally may support 204-byte packets with either 16 Reed-Solomon (RS) error correction bytes or 16 dummy bytes. In transport streams that do not fill the ASI pipe to maximum capacity, there are two ways to perform stuffing. In the first method, the pipe is filled full with MPEG packets by inserting null MPEG-2 packets when a data packet is not ready to be sent. In the second method, comma characters may be inserted either among the bytes within an MPEG-2 packet, between MPEG-2 packets, or any combination thereof. Essentially, they can be inserted anywhere. This fact alone necessitates full PCR correction in equipment that performs MPEG-2 interface adaptation from a DVB-ASI input stream.

Divicom M2S

Divicom's M2S interface is very similar to the DVB-ASI interface; however, there are differences in:

- the electrical interface,
- the physical connectors and cable,
- how stuffing bytes (comma characters) are inserted in the data stream, and
- the handling of packet synchronization.

The M2S interface requires that each data byte is followed by one comma character and that stuffing for lower data rates be performed either via null packets or by stuffing comma characters between MPEG packets, not within MPEG packets. There also must be a minimum of 31 comma characters between MPEG-2 packets. This limits the maximum data rate to 100 Mbps, about half that of DVB-ASI. Furthermore, to aid synchronization, the MPEG-2 sync byte (0x47) is encoded as an 8B/10B special character instead of as 8B/10B data.

The connectors are SMA for input, SMB for output, and the cable has a 50Ω characteristic impedance. The electrical levels also are much lower than ASI, thereby yielding a maximum cable length of 75 feet.

DVB-SSI

This is DVB's less popular synchronous serial interface. Like the other DVB interfaces, it is a point-to-point uni-directional link. The clock frequency varies depending on the data rate required by the MPEG-2 transport stream, with a maximum upper limit of 105 MHz. The DVB-SSI is a PS interface with the clock rate locked to the transport rate so that no stuffing is needed. In fact, if no error correction bytes are included, the data rate equals the raw clock rate. The SSI interface allows transport of 188-byte packets, or 204-byte packets with 16 bytes reserved for RS coding bytes or dummy bytes. Automatic packet type detection is performed using the sync byte's period of occurrence and inversion of the MPEG-2 sync byte to 0xB8 when valid

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error correction bytes are present.

At the physical layer, SSI supports a coax link, and a multi-mode or a single-mode fiber-optic link. Data is encoded using biphase mark encoding, which causes a transition of the encoded data signal on the starting edge of every data bit, and an additional transition in the middle of a "1" bit. Biphase mark encoding provides maximal data transitions to ease clock recovery, but at the expense of requiring twice the bandwidth of raw non-return to zero (NRZ) data. This encoding method also has an advantage in that it is polarity insensitive. Cable length is limited by a maximum allowable attenuation of 12dB at 700 MHz. For RG-59 cable, this corresponds to a length of about 450 feet.

SMPTE 310M

The 310M is SMPTE's synchronous serial interface and currently is the most dominant baseband MPEG-2 interface used in the broadcast industry. It was designed as a point-to-point unidirectional link for driving transmitter inputs and for sending pure MPEG-2 transport streams from one piece of equipment to another (e.g., from an encoder to a multiplexer). Maximum length is limited by the requirement that the signal not be attenuated by more than 3 dB at half the clock frequency. For 8-VSB transmission using RG-59 cable, the length is limited to approximately 300 feet.

The SMPTE 310M is a PS interface that operates at a fixed frequency of either 19.39 Mbps or 38.78 Mbps, and currently is being extended by SMPTE to the 80 Mbps range. In order to enable transmitters to use the clock as the source for carrier frequencies, the tolerance on clock jitter is very tight. Since the new 80-Mbps rate is not used by transmitters, this tight jitter requirement will most likely be relaxed. Since only transport streams with data rates equal to the supported fixed frequencies may be transported, there is no need for stuffing.

The SMPTE 310M uses a 75Ω source and destination terminated coaxial transmission medium with fiber channel (FC-0)-like levels. To ease clock extraction by the receiver, data is encoded and is sent MSB first using biphase mark encoding. Long-term clock stability is a very tight 2.8 PPM, with jitter constrained to be 2ns peak-to-peak over the frequency range of 1 Hz to 1/100th the clock frequency.

SMPTE 305M (SDTI)

The broadcast industry has used the point-to-point serial digital interface (SDI) SMPTE 259M for years to transmit digital component or composite video signals around studio facilities on simple coaxial cabling. SMPTE 259M is primarily a physical layer specification definining electrical aspects and data coding (for ease of clock recovery) of the link. It also defines video mapping for supported formats. SMPTE recently standardized a protocol layer compatible with 259M for the purpose of providing a means of transmitting any type of packetized digital data. This was adopted as SMPTE 305M—also referred to as serial data transport interface (SDTI). It relies upon the physical layer defined by 259M and the basic data structure of a SDI bitstream so that existing SDI cabling and SDI distribution amplifiers, switching and routing equipment in a facility, may be re-used.

SMPTE currently is in the process of standardizing mapping for MPEG-2 packetized data into SDTI. Once completed, MPEG-2 over SDTI will allow transport of MPEG-2-compressed video over 270 Mbps and 360 Mbps links. The SMPTE 305M is a PA interface—the interface clock frequencies are fixed and must accommodate various MPEG data packet rates. It also is one of the two interfaces being examined that encapsulate MPEG-2 data in an additional protocol layer. This enables the data format to be compatible with component digital video SDI. When combined with routers, and daisy chained through pieces of equipment, SDTI effectively can construct a network with a variety of topologies. The encapsulating data headers contain 128-bit IP style source and destination addresses, which can be used to route packets within a network. Routers will need to be upgraded to recognize this addressing scheme.

Figure 1 shows the basic SDI stream format for both 270 Mbps and 360 Mbps links. This encapsulation takes the form of start of active video (SAV) and end of active video (EAV) markers, which denote the start and end of a video line, respectively. The primary data payload is sandwiched between SAV- and EAV-reserved words in what is called the active line. Either 1440 or 1920 words are available for data depending on the speed of the link. Horizontal ancillary data is placed after the EAV marker and contains a very specific header data structure. The net effect of the overhead is a payload capacity of 200 Mbps to 225 Mbps for a 270 Mbps link, and 270 Mbps to 300 Mbps for a 360 Mbps link.

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Part II of this article will be included in the next Specs Technology issue (Vol. 11, No. 7).

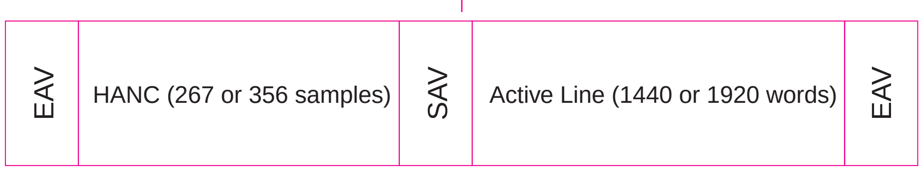

Figure 1. Fundamental Format of the SDI Bitstream